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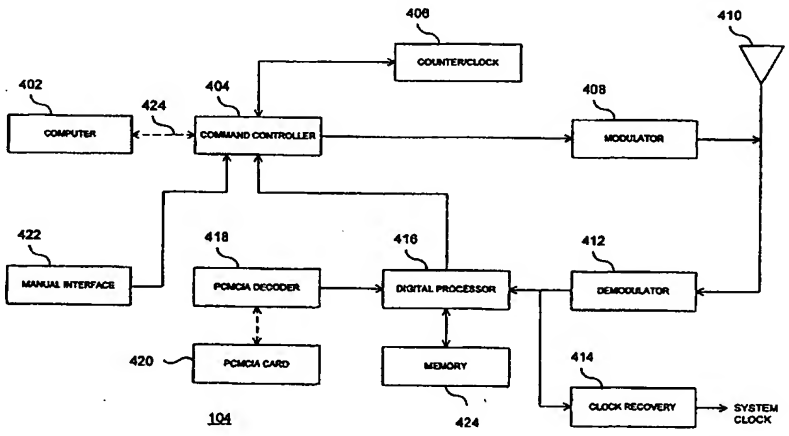

(57) Abstract

A system and method for conducting an inventory of tags, wherein each tag is assigned a Tag ID and a manufacturer number. Each tag can be attached to an item to take inventory of those items. A tag reader transmits a wake–up signal followed by at least one clock signal. Each tag increments a first tag count in response to the clock signals, and transmits the Tag ID assigned to the tag when the first tag count corresponds to the Tag ID assigned to the tag. The tag reader records the transmitted Tag IDs. When more than one tag transmits simultaneously, the tag stores the Tag ID in order to resolve the contention when the first read cycle is complete. In the second read cycle, the tag reader transmits the contended Tag ID followed by at least one clock signal. Each tag that contended for the transmitted Tag ID increments a second tag count in response to the clock signals, and transmits the manufacturer number assigned to the tag when the second tag count corresponds to the manufacturer number assigned to the tag. The tag reader records transmitted Tag IDs, completing the inventory of the tags.

System and Method for Electronic Inventory

Background of the Invention

Field of the Invention

The present invention relates generally to electronic inventory systems, and more particularly to the use of radio frequency identification (RFID) tags using anti-clash protocols.

Description of the Related Art

In modern business, maintaining an accurate inventory of merchandise is crucial. In the past, taking an inventory was an entirely manual process, and therefore slow and expensive. Modern automated inventory systems have improved the accuracy and speed of this process while reducing its cost. With the development of modern manufacturing methods, such as Just-In-Time Delivery, even faster and more accurate inventory methods are required. In some businesses, such as the baggage-handling aspect of the airline industry, inventories must be taken almost instantaneously.

Especially in the airline baggage handling industry, the need for quick and accurate inventories of bags cannot be exaggerated. In the past, the failure to match bags to passengers was merely an inconvenience. However, in the modern age of airline terrorism, the need to match passengers to bags has become a crucial safety concern. Following several airline bombings, the Commission on Aviation Safety and Security issued several recommendations to President Clinton on September 5, 1996 to combat such terrorism. One of the recommendations stated: "Match passengers to their bags to ensure that the baggage of anyone who does not board the plane is removed."

One approach to electronic inventory systems is the use of RFID tags. In such systems, an RFID tag is attached to each item to be inventoried. Each tag

manufacturer number assigned to the tag. The tag reader records the transmitted Tag IDs, completing the inventory of the tags.

Brief Description of the Figures

The present invention will be described with reference to the accompanying drawings.

FIG. 1 depicts a tag reader and a plurality of tags according to the present invention for use in an electronic inventory system.

FIG. 2 is a flowchart depicting the operation of the present invention according to a preferred embodiment.

FIG. 3 is a circuit block diagram of an RFID tag according to a preferred embodiment of the present invention.

FIG. 4 is a circuit block diagram of the architecture of tag reader 104 according to a preferred embodiment.

FIG. 5 is a flowchart depicting a first read operation of a timed broadcast read of the present invention.

FIG. 6 is a flowchart depicting a second read operation of a timed broadcast read of the present invention.

FIG. 7 is a flowchart depicting a third read operation of a timed broadcast read of the present invention.

FIG. 8 is a flowchart depicting a method of manufacture for the RFID tag of the present invention.

FIG. 9 depicts a pair of tags according to the present invention.

FIG. 10 is a flowchart depicting an example use of an embodiment of the present invention in the airline baggage handling industry.

of manufacture, the wafer number of the integrated circuit on the tag, etc. In a preferred embodiment, the Tag ID, manufacturer number and lot number are laser-programmed into the tag at the time of tag manufacturer. Therefore, these values are permanently fixed at the time of manufacture and cannot subsequently be changed.

Referring to FIG. 1, in a preferred embodiment of the present invention, tag reader 104 emits a series of clock instructions. Each clock instruction defines a time slot. Tags 102 count the time slots. When the time slot count is equivalent to the Tag ID programmed into a tag, the tag transmits its Tag ID to tag reader 104. In this way, tag reader 104 accumulates the Tag IDs of the inventory tags.

FIG. 2 is a flowchart depicting the operation of the present invention according to a preferred embodiment. The flowchart illustrates the present invention's use of multiple reads and multiple tag identifiers to avoid time slot contention. Referring to FIG. 2, the tags are read for the first time as described above with respect to FIG. 1, and as shown in a step 202. If no time slot contention is detected, as shown by the "no" branch from step 204, then the inventory is complete and accurate.

As described above, time slot contention occurs when multiple tags transmit to the reader in the same time slot. The tag reader can detect this contention in many ways that are well known in the art. For example, each tag could error-code its transmission, for example by using a checksum. When the tag reader receives a tag transmission, it computes a checksum. If two tags transmit simultaneously, the computed checksum will not match the transmitted checksum. When tag reader 104 determines that these checksums do not match, then time slot contention has been detected. Other methods of detecting time slot contention may be employed with the present invention without departing from its spirit and scope.

If during the first tag read contention was detected, as shown by the "yes" branch from step 204, then a second tag read is performed, as shown in a step 206. While the first tag read was based on Tag IDs, the second tag read is based

embodiment antenna 302 is an omnidirectional antenna, with its impedance matched to the frequency of transmission.

In the depicted embodiment, system power for each tag is provided by a charging signal transmitted by the reader prior to the tag reading operation. Power converter circuit 304 is used to convert the received charging signal to system power. Such power converter circuits are well known in the art. In a preferred embodiment, the charging signal need only be present for a short time to fully charge the tags. In an alternative embodiment, power converter 304 is replaced by a battery. In that embodiment, the tag reader 104 is not required to transmit a charging signal.

Demodulator 306 receives signals from tag reader 104 via antenna 302. In a preferred embodiment, the received signals comprise a charging signal and one or more instructions. These instructions are described in detail below. One such instruction includes a count instruction that instructs the tags to increment their counter/shift registers 312. In one embodiment, the count instruction causes counter/shift registers 312 to increment by one; in alternative embodiments, the instruction causes counter/shift registers 312 to increment by other values.

In a preferred embodiment, the instructions are transmitted by tag reader 104 using a phase-modulated RF signal using a several hundred kilohertz baud rate and a 900 megahertz carrier frequency. The instructions are sent by the reader with a "return to center" data format; this format is well-known in the art. The instructions are decoded by the tag to generate digital input for instruction interpreter 310 and a system clock. The system clock is recovered by clock recovery circuit 308.

Instruction interpreter 310 receives instructions from demodulator 306, and provides control signals and data to counter/shift register 312 and multiplexer 318. Laser programmable taps 314a - 314c are permanently programmed with predetermined values at the time of tag manufacture. In a preferred embodiment, taps 314a - 314c are programmed by laser-cutting specific output taps of a collection of inverters. As would be apparent to one skilled in the relevant arts,

scatter signals. In a preferred embodiment a several hundred kilohertz baud rate is used with a 900 megahertz carrier frequency. Because the tag system clock is derived from the signal provided by the tag reader, the data sent by the tag to the reader is clock-synchronized with the reader.

In one embodiment, tag 102 also contains one or more sensors. Data collected by the sensors is routed to counter/shift register 312 each time tag 102 transmits. The sensor data is appended to the tag transmission and recorded by tag reader 104. In one embodiment, the sensor is a gas sensor that detects the presence of chemicals associated with drugs or precursor chemicals of explosives, such as methane. When a tag equipped with such a sensor is used as a baggage tag, it is a powerful mechanism for quickly locating bags containing contraband or explosives.

The architecture of tag reader 104 is now described. FIG. 4 is a circuit block diagram of the architecture of tag reader 104 according to a preferred embodiment. The circuitry of tag reader is described in three categories: generic circuitry, processing circuitry, and application-specific circuitry.

Referring to FIG. 4, tag reader processing circuitry is represented by computer 402. Computer 402 performs high level processing functions not provided by tag reader generic circuitry. These high level functions include compiling inventory lists, handling time slot contentions, and the like, as would be apparent to one skilled in the relevant art. Computer 402 may be physically co-located with tag reader 104, as in the case of a stationary tag reader, or may be physically separate from tag reader 104, as may be the case with a hand-held or portable tag reader. The connection 424 between computer 402 and command controller 404 may be hard-wired or wireless.

Application-specific tag reader circuitry is represented by PCMCIA (Personal Computer Memory Card International Association) card 420. In a preferred embodiment, details regarding specific tags, applications, encryption scheme, sensor configuration and data, and modes of operation to be used can be embodied in PCMCIA card 420. In this embodiment, a generic tag reader 104 can

Modes of Operation - Timed Broadcast Read

As described above, the present invention provides at least three modes of operation: timed broadcast read, immediate read, and specific tag read. Timed broadcast read allows an ensemble of tags (from a few to several thousand) to be read within a time frame of a few seconds. FIG. 2 is a high-level flowchart of the timed broadcast read mode of operation of the present invention. FIG. 5 is a flowchart depicting the first read operation of the timed broadcast read of the present invention. During the first read operation, the tag reader steps the tags through a sequence of time slots. When a tag detects that a time slot matches its preprogrammed time slot, the tag transmits its Tag ID. If more than one tag transmits in the same time slot, the tag reader stores the time slot number for future resolution of the time slot contention.

First Read Cycle

Referring to FIG. 5, the timed broadcast read mode of operation begins when the tag reader transmits a first instruction alert to the tags, as shown in a step 502. The first instruction alert signals to the tags that this is the first instruction in the timed broadcast read mode of operation. In response, the tags initialize. In particular, the tags initialize their counters /shift registers 312, as shown in a step 504. The tag reader then repeatedly transmits a clock increment instruction, as shown in a step 506. In response to the increment instruction, each tag increments the count in its counter/shift register 312, as shown in Step 508. When a tags counter/shift register 312 output matches the Tag ID programmed into Tag ID taps 314a, as indicated by the "yes" branch from step 510, the tag transmits its Tag ID as shown in a step 512 and described above.

In an alternative embodiment, the tag does not transmit its Tag ID, but instead transmits a simple response signal, when a tags counter/shift register 312 output matches the Tag ID programmed into Tag ID taps 314a. The response signal need not convey any information describing the identity of the tag. Indeed, the response signal need not convey any information at all. The response signal

in the same time slot during the second read. Therefore, Tag ID contention is resolved by the second read. In the unlikely event that multiple tags have the same Tag ID and manufacturer number, contention can be resolved using a third read cycle, as described below.

Referring to FIG. 6, tag reader 104 initiates the second read cycle by sending a second read mode instruction to tags 102, as shown in a step 602. The reader then transmits a contended Tag ID to the tags, as shown in a step 604. The step permits only those tags that contended for a particular Tag ID to participate in contention resolution for that Tag ID. In response to the transmission of the contended Tag ID, only those tags having that Tag ID initialize their counters/shift registers 312, as shown in a step 606.

Tag reader 104 then transmits the first in a series of increment instructions, as shown in a step 608. In response, the contending tags increment their counter/shift registers 312, as shown in a step 610. When the output of a tag's counter/shift register 312 matches the tag manufacturer number permanently programmed into manufacturer number taps 314b, as indicated by the "yes" branch from step 612, the tag transmits its manufacturer number, as shown in a step 614.

In an alternative embodiment, the tag transmits a simple response signal as described above. Tag reader 104 then records the tag's manufacturer number by storing the count in its counter/clock 406, as described above for the Tag ID.

If more than one tag transmits its manufacturer number simultaneously, tag reader 104 detects the contention, as indicated by the "yes" branch from step 616, and tag reader 104 stores the contended manufacturer number for future contention resolution in a third read cycle, as shown in a step 618.

Tag reader 104 steps tags 102 through a predetermined range of possible manufacturer numbers. When the last count is reached, as indicated by the "yes" branch from step 620, the process of steps 604 through 618 is repeated for the next contended Tag ID. When the last contended Tag ID has been examined, as indicated by the "yes" branch from step 622, the second read cycle is complete.

into lot number taps 314c, as indicated by the "yes" branch from step 712, the tag transmits its manufacturer number, as shown in a step 714.

In an alternative embodiment, the tag transmits a simple response signal as described above. Tag reader 104 then records the tag's lot number by storing the count in its counter/clock 406, as described above for the Tag ID.

If more than one tag transmits its lot number simultaneously, tag reader 104 detects the contention, as indicated by the "yes" branch from step 716, and tag reader 104 stores the contended manufacturer number for future contention resolution in a further read cycle, as shown in a step 718.

Tag reader 104 steps tags 102 through a predetermined range of possible lot numbers. When the last count is reached, as indicated by the "yes" branch from step 720, the process of steps 704 through 718 is repeated for the next contended manufacturer number. When the last contended manufacturer number has been examined, as indicated by the "yes" branch from step 722, the third read cycle is complete.

Immediate Read

Immediate read mode is used to read individual tags one at a time. In this mode, tag reader 104 transmits an instruction to a tag 102 that causes the tag to bypass the time slot counting operation and to immediately transmit its Tag ID number. This mode is useful for rapid Tag identification (on the order of milliseconds) when the individual tag rapidly passes through the reader zone. An example application is the reading of tags affixed to automobiles passing through an automatic toll booth.

indication of tampering. Tear lines 912 can be placed across critical portions of the tag circuitry, such as antenna 302a, such that tag separation along tear line 912 renders the tag inoperative.

As described above, tag 102 is powered by a power source, such as a battery, in one embodiment. In this embodiment, the battery may be formed by placing an anode 910a in one joining area 914a of the tag and placing a cathode 910c in the other joining area of the tag 914b. At least one of anode 910a and cathode 910c is coated with a electrolytic material and covered by a release liner. In another embodiment, tag 102 is powered by a capacitor. In that embodiment, at least one of anode 910a and cathode 910c is coated with a dielectric material and covered by a release liner. Other power sources may be used with tag 102 without departing from the spirit and scope of the present invention, as would be apparent to one skilled in the relevant art.

The ticket agent joins the two joining areas 914a,b of tag 102 by removing the release liner and joining cathode 910c to anode 910a, thereby forming the power source of the tag. Any attempt to separate areas 914a,b after joining will destroy the power source formed by anode 910a and cathode 910c, thereby rendering the tag inoperative. In another embodiment, separating areas 914a,b after joining also gives a visual indication of tampering. For example, separating areas 914a,b could reveal a large "VOID" sign or some other image or break pattern.

Now the manufacture of tag 102 according to a preferred embodiment is described with reference to FIG. 8. In a step 804 one or more ASICs are manufactured. The ASICs include the inventory response circuitry depicted in FIG. 3. The circuitry includes the circuit elements of FIG. 3 except antenna 302. In one embodiment, all inventory response circuitry is contained upon a single ASIC. In another embodiment, RF circuitry is contained on one ASIC, and digital circuitry is contained on another ASIC. Then, in a step 806, the ASIC containing the digital inventory response circuitry is permanently programmed with at least the Tag ID and manufacturer number. In one embodiment the ASIC is also

Airline Baggage Handling Example

As described above, the present invention is ideally suited to use in the airline baggage handling industry. An example of this use is presented in the flowchart of FIG. 10. The process begins when a passenger approaches the ticket counter or curbside check-in at the airport, as shown in Step 1004. The passenger then presents his ticket and/or a personal identification in a step 1006. The system captures this information; the system can also capture other authentication information such as biometrics, as show in a step 1008. When the passenger presents his baggage for check-in, as shown in step 1010, the ticket agent applies a tag to each bag and to the passenger's ticket. In a preferred embodiment, each of these tags bears an identical Tag ID, manufacturer number, and lot number. The system records the Tag ID, flight number, and passenger identity, as shown in a step 1018.

After the bag is sent down the chute to the distribution area, as shown in a step 1022, it is placed on a baggage cart in accordance with the flight number conventionally printed on the baggage tags, as shown in a step 1024. Once on the baggage cart, the bag tags are read to determine the Tag IDs. If the Tag IDs indicate that the bags are not on the proper baggage cart, as indicated by the "no" branch from step 1030, then the bags are visually inspected and redirected to the correct baggage cart, as shown in a step 1028.

The bags are then transported to the proper gate, loaded onto the designated airplane and then read again, as shown in steps 1034, 1036 and 1038. Once on the airplane in the cargo hold, the bags are read again, as shown in a step 1038. If the tag inventory determines that the bags are not on the proper plane, as indicated by the "no" branch from step 1040, then the system sounds an alert, as shown in a step 1056. Alternatively, the bags can be read on the conveyor belt before they are loaded into the cargo hold. After the alert is sounded, the bag can be removed and examined for re-routing as shown in a step 1058.

Once passenger boarding has begun, an inventory of passengers can be performed by scanning the tags on the passenger tickets. If a mismatch is detected

center of a compact disk, or the case of a videocassette, to facilitate both overt and covert operation.

The store maintains an inventory database of all the articles within the store. Each entry in the database represents a garment and contains the Tag ID of the tag embedded in the article. The entry also indicates whether the item has been purchased. When a tag of an unpurchased article is detected by a door reader, an alarm is sounded, indicating that the article is being shoplifted.

When an item is purchased, its tag ID is removed from the inventory database. Therefore, when a tag attached to a purchased article moves past the door reader, no alarm is sounded. Used alone or with security cameras, the present invention provides an effective tool to combat shoplifting.

In another embodiment, the present invention could be used to implement an "unattended store," i.e. one with no salespersons or clerks. A customer could enter the store, select items and go to a purchasing area. In the purchasing area, a tag reader would identify the customer's selections. The customer would then be presented with a bill. The customer could pay the bill with a credit card, whereupon the unattended store would remove the purchased item from its inventory database. The customer could then leave the store with the purchases.

Example Instruction Set

Now an instruction set is described that can be used with the present invention. As would be apparent to one skilled in the relevant art, other instructions can be employed with the present invention without departing from its spirit and scope. In a preferred embodiment, the reader sends an instruction stream to the tag instruction register that is Nir bits long, where Nir is the number of stages in the instruction register. The instructions have the following data field format and symbolic binary values:

Np: Preamble: alerts the tags that the reader is starting communication. This data field is useful to prevent spurious noise from "spoofing" the tags and to initialize and synchronize the tag clock. The preamble starts with a long stream

Nr; Specific tag read: When the symbolic binary form is " 1", this field instructs the tag to go into the specific tag read mode as designated by Nt, above. The reader will cycle through three instructions to set the tag to the proper state. The first is with Nt=001 and sets the Tag ID counter for the targeted tag. The second is with Nt= 010 and sets up the second counter with the targeted manufacturer number. The third is with Nt= 100 and sets up the third counter with the targeted lot number. Then the reader sends out clock with Nt=111 to read only the targeted tag at every clock instruction.

Nm; Clock/Count: This field sets the counter shift registers (SR's) into either the clocked mode to increment the counter by the next clock signal, or into the SR mode, awaiting the following time slot, wafer/lot number, or date instruction stream. It has the symbolic binary form:

- Clocked mode: 01
- Specific count: 10

Ns; Clock signal/time slot. This data field contains either specific counter instruction data, or a stream of zeroes if the tag is being instructed into the count mode. The symbolic binary form is "1" when there is a specific counter instruction, and "0" for the count mode. When Nm=01 and Ns=0, a clock instruction counter, Nc, is enabled.

Nc: Clock instruction signal to increment counter/shift registers 312. The symbolic binary form is:

- No clock instruction: 00
- Clock: 01
- Last clock: 11

The clock instruction counter, Nc, allows the reader to "short cycle" the tag through the count sequence, bypassing the Nir instruction sequence, which can be

Immediate Read:	**Nc/Ns/Nm/Nr/Ni/Nt / Nw / Np**
Initialization:	00/ 0 / 00 / 0 / 0 / 000 / 000 / 0
First instruction:	00 / 0 / 00 / 0 / 1 / 000 / 001 / 1
Next and last instruction (tag turns off):	00 / 0 / 00 / 0 / 0 / 000 / 100 / 1

Specific Tag Read:	**Nc/Ns/Nm/Nr/Ni/Nt / Nw / Np**
Initialization:	00 / 0 / 00 / 0 / 0 / 000 / 000 / 0
First instruction:	00 / 1 / 10 / 1 / 0 / 001 / 001 / 1
Second instruction:	00 / 1 / 10 / 1 / 0 / 010 / 010 / 1
Third instruction:	00 / 1 / 10 / 1 / 0 / 100 / 010 / 1
Following clock instructions:	01 / 0 / 01 / 1 / 0 / 111 / 010 / 1
Last clock instruction:	11 / 0 / 01 / 0 / 0 / 111 / 010 / 1
First instruction of next specific read:	00 / 1 / 10 / 1 / 0 / 001 / 010 / 1
Second instruction of next read:	00 / 1 / 10 / 1 / 0 / 010 / 010 / 1
Third instruction of next read:	00 / 1 / 10 / 1 / 0 / 100 / 010 / 1
Following clock instructions:	01 / 0 / 01 / 1 / 0 / 111 / 010 / 1
Last clock instruction:	11 / 0 / 01 / 0 / 0 / 111 / 010 / 1
Last instruction (tag turns off):	00 / 0 / 00 / 0 / 0 / 000 / 100 / 1

Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

2. The method of claim 1, wherein a ticket tag is attached to each passenger's ticket and each ticket tag is permanently assigned the Tag ID and the manufacturer number of the bag tag attached to the passenger's bag, further comprising the steps of:

conducting an inventory of the ticket tags according to the method of claim 1; and

comparing said inventory of ticket tags to the inventory of bag tags to ensure that each passenger and said each passenger's bags board the same vehicle.

3. The method of claim 1, wherein:

each bag tag is permanently assigned a tag ID and a manufacturer number at the time of manufacture.

4. The method of claim 1, wherein at least one bag tag includes a sensor, further comprising the step of:

at the at least one bag tag, transmitting the contents of said sensor.

5. A tag for use in conducting an inventory of passenger bags, wherein each bag is attached to a tag and each tag is permanently assigned a tag identification number (Tag ID) and a manufacturer number, the tag comprising:

means for receiving a wake-up signal followed by at least one first clock signal;

means for incrementing a first tag count in response to said at least one first clock signal;

means for transmitting the Tag ID assigned to the tag when said Tag ID corresponds to said first tag count;

means for receiving at least one second clock signal;

means for incrementing a second tag count in response to said at least one second clock signal; and

means for transmitting the manufacturer number assigned to the tag when said manufacturer number of said each tag corresponds to said second count.

at each tag, transmitting a permanent identification number assigned to said each tag when said permanent identification number assigned to said each tag corresponds to said time slot number.

10. A system for conducting an inventory of tags, wherein each tag is assigned a permanent identification number, the system comprising:

at a tag reader, means for transmitting a wake-up signal followed by at least one clock signal; and

at each tag,

means for incrementing a tag count in response to said at least one clock signal, and

means for transmitting the permanent identification number assigned to said each tag when said permanent identification number of said each tag corresponds to said tag count.

11. The system of claim 10, further comprising:

at said tag reader, means for transmitting an instruction to perform a tag read.

12. The system of claim 10, wherein the duration of tag transmissions is fixed, further comprising:

at said tag reader, means for transmitting a further one of said at least one clock signal after the tag transmission duration has elapsed.

13. The system of claim 10, further comprising:

at said tag reader, means for transmitting a further one of said at least one clock signal after a tag response time has elapsed, wherein said tag response time is the maximum duration of time between a tag reader transmission and the reception at said tag reader of a corresponding tag transmission.

14. The system of claim 10, further comprising:

22. The system of claim 21, wherein each tag is assigned a second permanent identification number, further comprising:

at said tag reader, means for transmitting said given reader count followed by at least one second clock signal; and

at each tag that responded to said one of said at least one clock signal that corresponds to said given reader count,

means for incrementing a second tag count in response to said at least one second clock signal, and

means for transmitting the second permanent identification number assigned to said each tag when said second permanent identification number of said each tag corresponds to said second count.

23. The system of claim 22, further comprising:

at said tag reader, means for transmitting an instruction to perform a second tag read.

24. The system of claim 22, further comprising:

at said tag reader, means for incrementing a second reader count in response to said at least one second clock signal.

25. The system of claim 24, further comprising:

at said tag reader, means for indicating an error when said second reader count does not correspond to said second permanent identification number.

26. The system of claim 24, further comprising:

at said tag reader, means for storing said given reader count and a given second reader count when more than one tag responds to one of said at least one second clock signal that corresponds to said given second reader count.

incrementing a tag count in response to said at least one clock signal, and transmitting the permanent identification number assigned to said each tag when said permanent identification number of said each tag corresponds to said tag count.

32. The method of claim 31, further comprising the step of:
at said tag reader, transmitting an instruction to perform a tag read.

33. The method of claim 31, wherein the duration of tag transmissions is fixed, further comprising the step of:
at said tag reader, transmitting a further one of said at least one clock signal after the tag transmission duration has elapsed.

34. The method of claim 31, further comprising the step of:
at said tag reader, transmitting a further one of said at least one clock signal after a tag response time has elapsed, wherein said tag response time is the maximum duration of time between a tag reader transmission and the reception at said tag reader of a corresponding tag transmission.

35. The method of claim 31, wherein:
each bag tag is permanently assigned a tag ID and a manufacturer number at the time of manufacture.

36. The method of claim 31, wherein at least one bag tag includes a sensor, further comprising the step of:
at the at least one bag tag, transmitting the contents of said sensor.

37. The method of claim 31, wherein said permanent identification number is encrypted.

transmitting the second permanent identification number assigned to said each tag when said second permanent identification number of said each tag corresponds to said second count.

44. The method of claim 43, further comprising the step of:

at said tag reader, transmitting an instruction to perform a second tag read.

45. The method of claim 43, further comprising the step of:

at said tag reader, incrementing a second reader count in response to said at least one second clock signal.

46. The method of claim 45, further comprising the step of:

at said tag reader, indicating an error when said second reader count does not correspond to said second permanent identification number.

47. The method of claim 45, further comprising the step of:

at said tag reader, storing said given reader count and a given second reader count when more than one tag responds to one of said at least one second clock signals that corresponds to said given second reader count.

48. The method of claim 47, wherein each tag is assigned a third permanent identification number, further comprising the steps of:

at said tag reader, transmitting said given reader count and said given second reader count followed by at least one third clock signal;

at each tag that responded to said one of said at least one second clock signal that corresponds to said given second reader count,

incrementing a third tag count in response to said at least one third clock signal, and

means for recording said reader count when one of said response signals is received, thereby recording the presence of the tag that transmitted said one of said response signals.

53. The system of claim 52, further comprising:

at said tag reader, means for transmitting an instruction to perform a tag read.

54. The system of claim 52, wherein the duration of tag transmissions is fixed, further comprising:

at said tag reader, means for transmitting a further one of said at least one clock signal after the tag transmission duration has elapsed.

55. The system of claim 52, further comprising:

at said tag reader, means for transmitting a further one of said at least one clock signal after a tag response time has elapsed, wherein said tag response time is the maximum duration of time between a tag reader transmission and the reception at said tag reader of a corresponding tag transmission.

56. The system of claim 52, further comprising:

at each tag,

a sensor; and

means for transmitting the contents of said sensor.

57. The system of claim 52, further comprising:

means for transmitting a charging signal, thereby energizing the tags.

58. The system of claim 52, further comprising:

at said tag reader, means for storing a given reader count when more than one tag responds to one of said at least one clock signal that corresponds to said given reader count.

at said tag reader,

means for transmitting said given reader count and said given second reader count followed by at least one third clock signal, and

means for incrementing a third reader count in response to said at least one third clock signal;

at each tag that responded to said one of said at least one second clock signal that corresponds to said given second reader count,

means for incrementing a third tag count in response to said at least one third clock signal, and

means for transmitting a third response signal when said third permanent identification number of said each tag corresponds to said third tag count; and

at said tag reader,

means for recording said third reader count when one of said third response signals is received, thereby recording the presence of the tag that transmitted said one of said third response signals.

63. The system of claim 62, further comprising:

at said tag reader, means for transmitting an instruction to perform a third tag read.

64. A method for conducting an inventory of tags, wherein each tag is assigned a permanent identification number, the method comprising the steps of:

at a tag reader,

transmitting a wake-up signal followed by at least one clock signal, and

incrementing a reader count in response to said at least one clock signal;

at each tag,

incrementing a tag count in response to said at least one clock signal, and

at said tag reader, storing a given reader count when more than one tag responds to one of said at least one clock signal that corresponds to said given reader count.

71. The method of claim 70, wherein each tag is assigned a second permanent identification number, further comprising the steps of:

at said tag reader,

transmitting said given reader count followed by at least one second clock signal, and

incrementing a second reader count in response to said at least one second clock signal;

at each tag that responded to said one of said at least one clock signal that corresponds to said given reader count,

incrementing a second tag count in response to said at least one second clock signal, and

transmitting a second response signal when said second permanent identification number of said each tag corresponds to said second count; and

at said tag reader,

recording said second reader count when one of said second response signals is received, thereby recording the presence of the tag that transmitted said one of said second response signals.

72. The method of claim 71, further comprising the step of:

at said tag reader, transmitting an instruction to perform a second tag read.

73. The method of claim 71, further comprising the step of:

at said tag reader, storing said given reader count and a given second reader count when more than one tag responds to one of said at least one second clock signal that corresponds to said given second reader count.

flip-chip bonding said ASIC to said bonding pads using a conductive adhesive.

77. The method of claim 76, further comprising the step of:

applying an attachment means to a first portion of the tag, whereby said first portion may be joined to a second portion of the tag to close the tag about an object to be tagged; and

perforating said tag so that any attempt to remove a close tag from a tagged object renders the tag inoperative.

78. The method of claim 76, wherein

said attachment means is an adhesive.

79. The method of claim 76, further comprising the steps of:

preprinting an anode on a first portion of said flexible substrate;

preprinting a cathode on a second portion of said flexible substrate;

applying at least one of a dielectric material and an electrolytic material to at least one of said anode and said cathode; and

applying an attachment means to at least one of said anode and said cathode;

whereby a power supply means is formed by the subsequent attachment of said anode and said cathode using said attachment means, and said power supply means is destroyed by any attempt to thereafter detach said anode and said cathode.

80. The method of claim 77, wherein

said attachment means is an adhesive.

81. The method of claim 76, further comprising the step of:

hermetically sealing said ASIC.

82. The method of claim 76, further comprising the steps of:

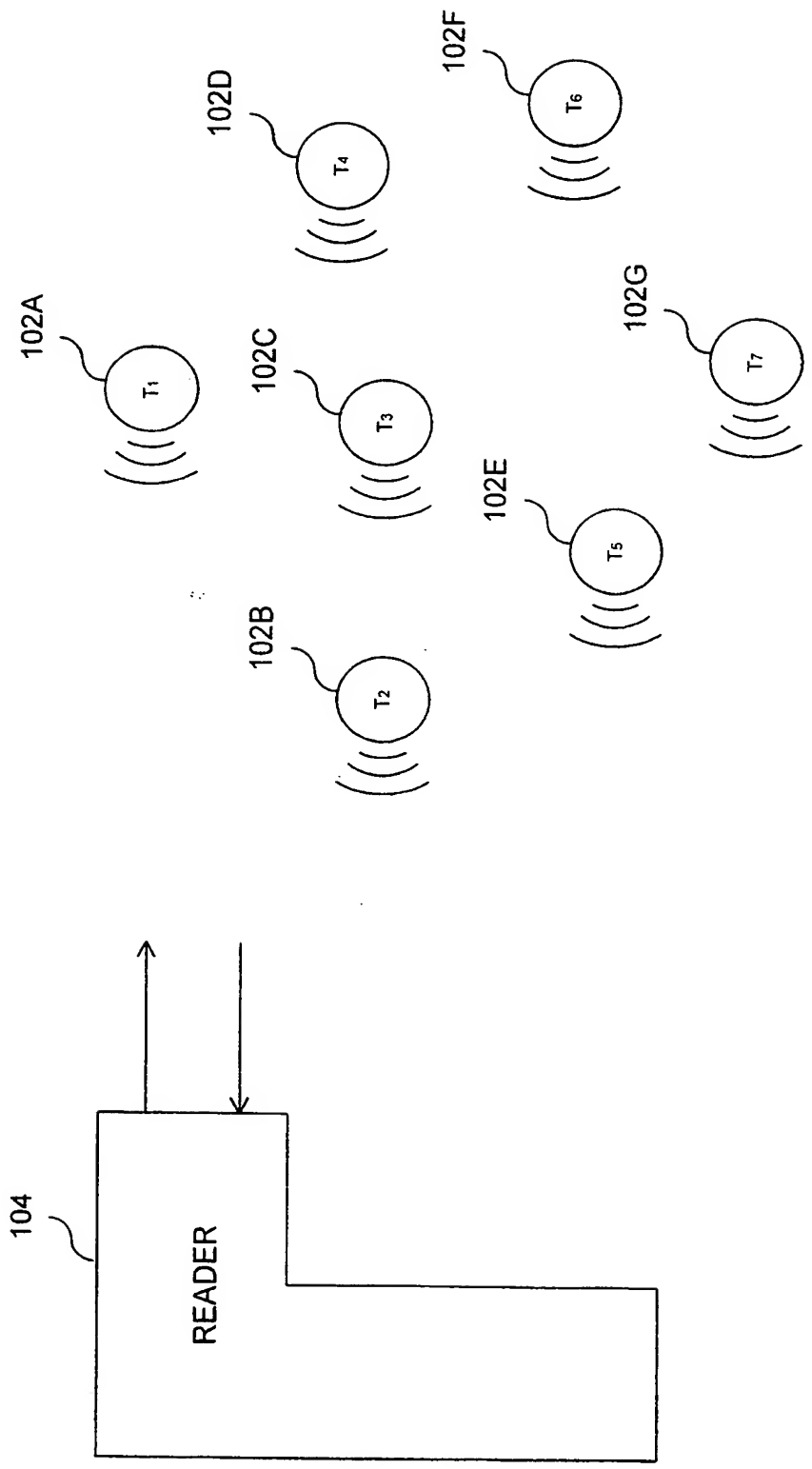
102A
T1
102B
T2
102C
T3
102D
T4
102E
T5
102F
T6
102G
T7
104
READER

FIG. 1

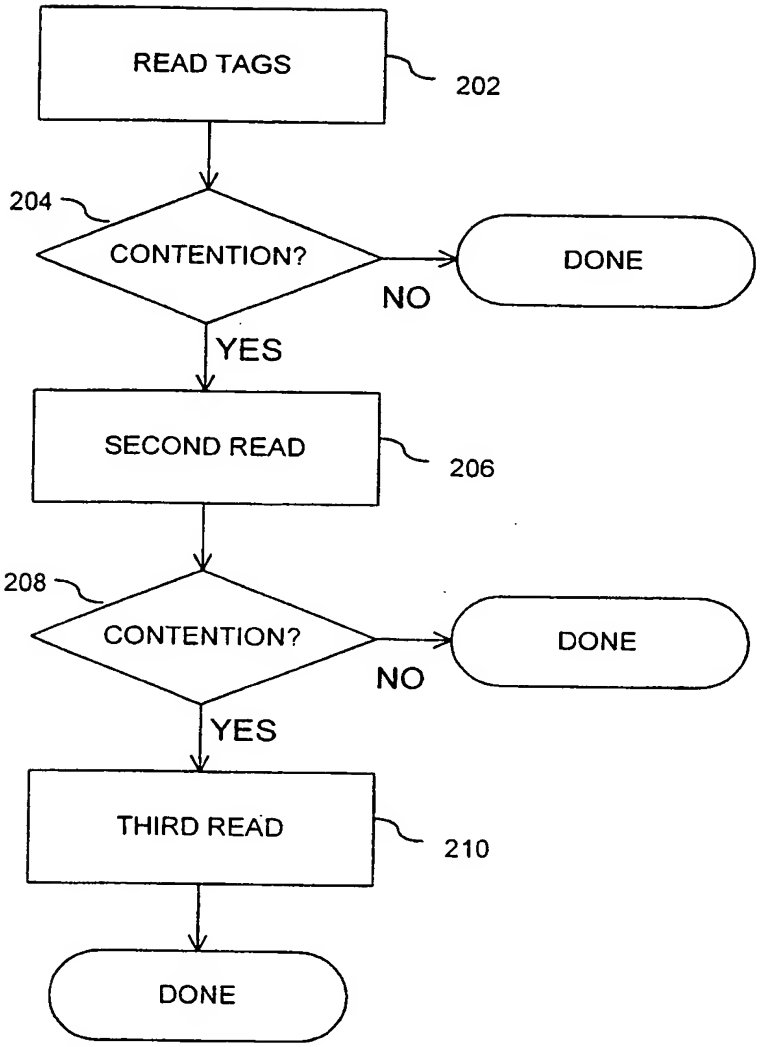
READ TAGS
202
204
CONTENTION?
DONE
NO
YES
SECOND READ
206
208
CONTENTION?
DONE
NO
YES
THIRD READ
210
DONE

FIG. 2

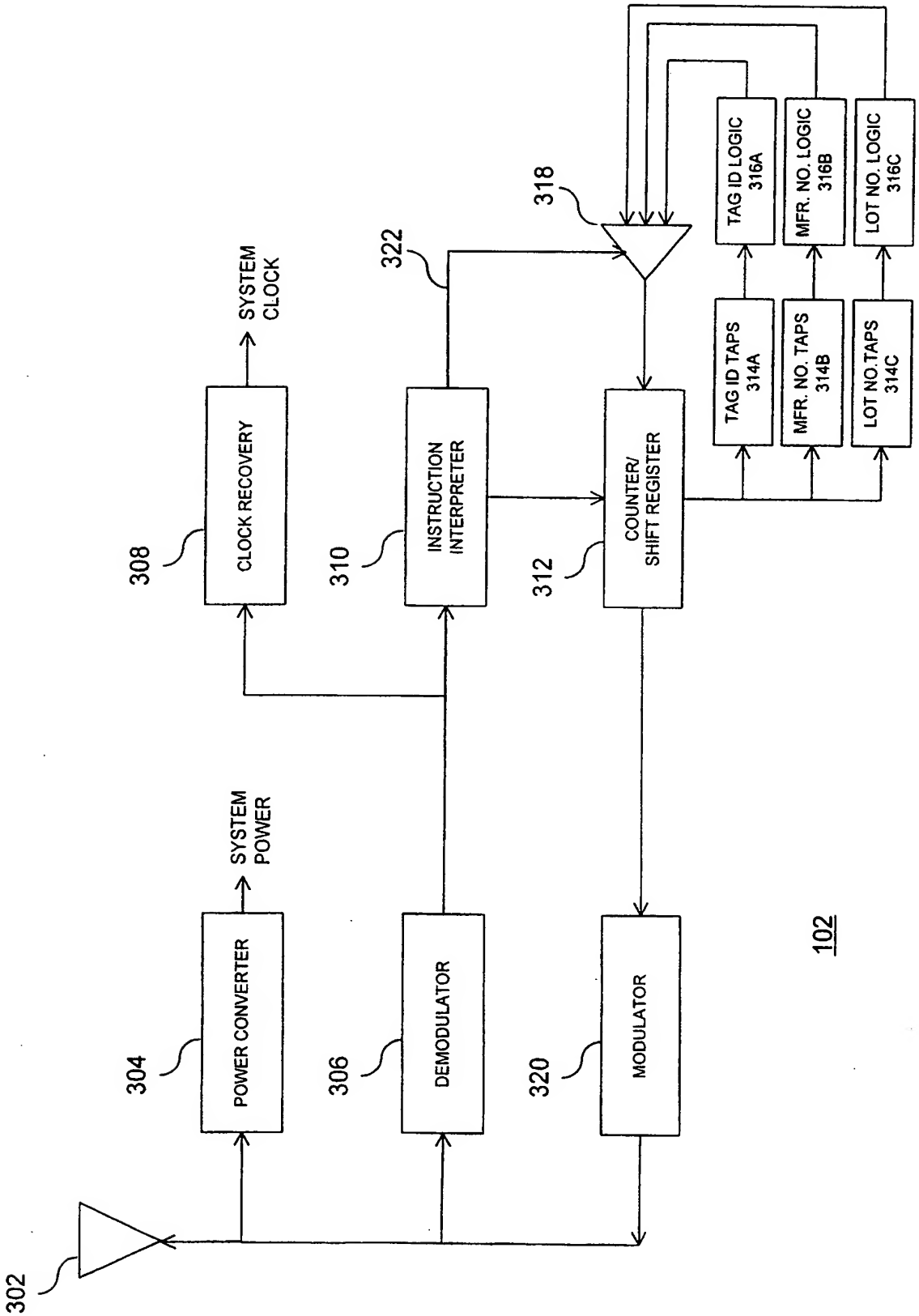
302
304
POWER CONVERTER
SYSTEM POWER
306
DEMODULATOR
308
CLOCK RECOVERY
SYSTEM CLOCK
310
INSTRUCTION INTERPRETER
312
COUNTER/ SHIFT REGISTER
318
320
MODULATOR
322
TAG ID TAPS 314A
MFR. NO. TAPS 314B
LOT NO. TAPS 314C
TAG ID LOGIC 316A
MFR. NO. LOGIC 316B
LOT NO. LOGIC 316C
102

FIG. 3

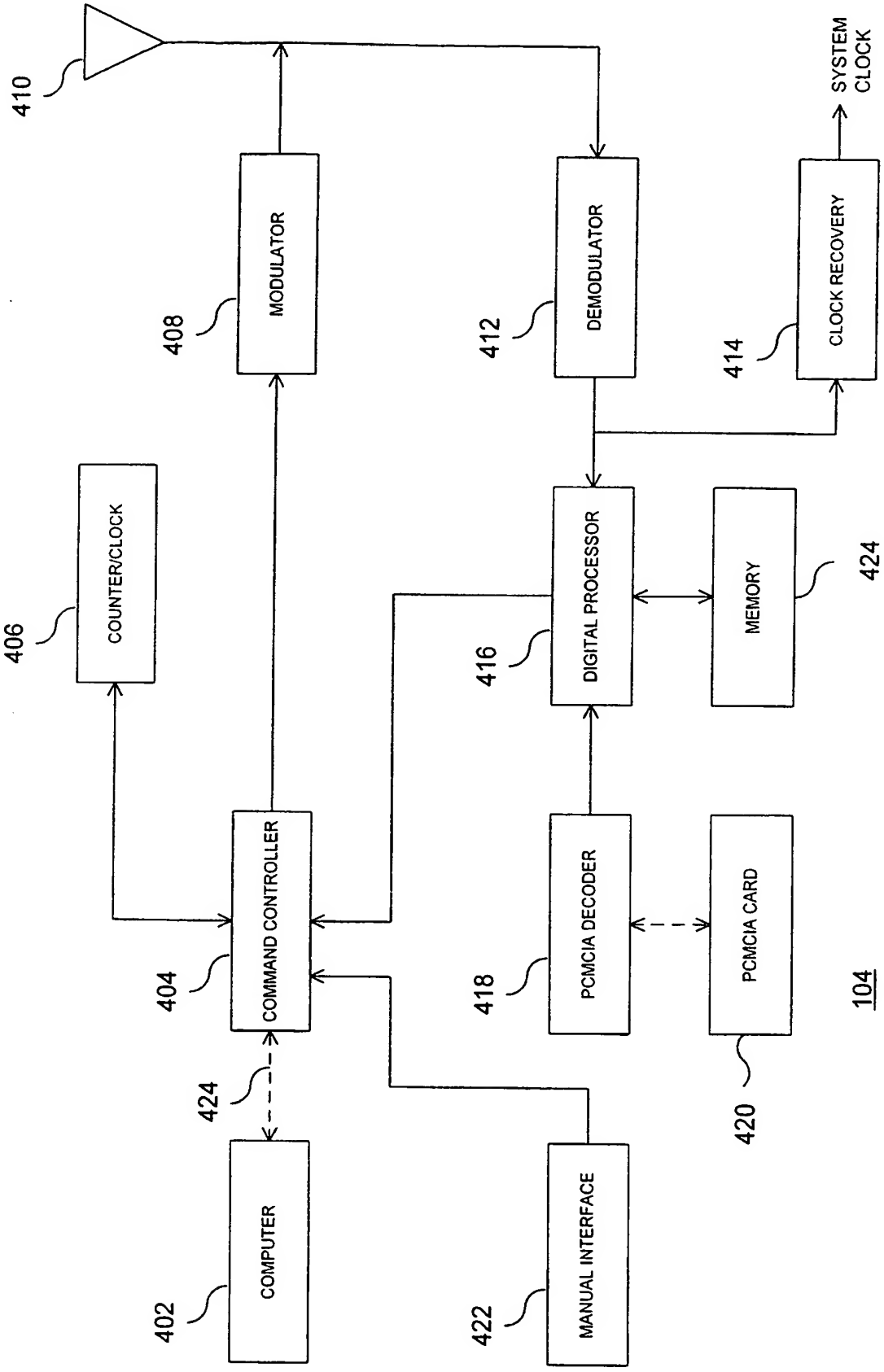
410
MODULATOR
408
DEMODULATOR
412
CLOCK RECOVERY
414
SYSTEM CLOCK
COUNTER/CLOCK
406
DIGITAL PROCESSOR
416
MEMORY
424
COMMAND CONTROLLER
404
PCMCIA DECODER
418
PCMCIA CARD
420
104
424
COMPUTER
402
MANUAL INTERFACE
422

FIG. 4

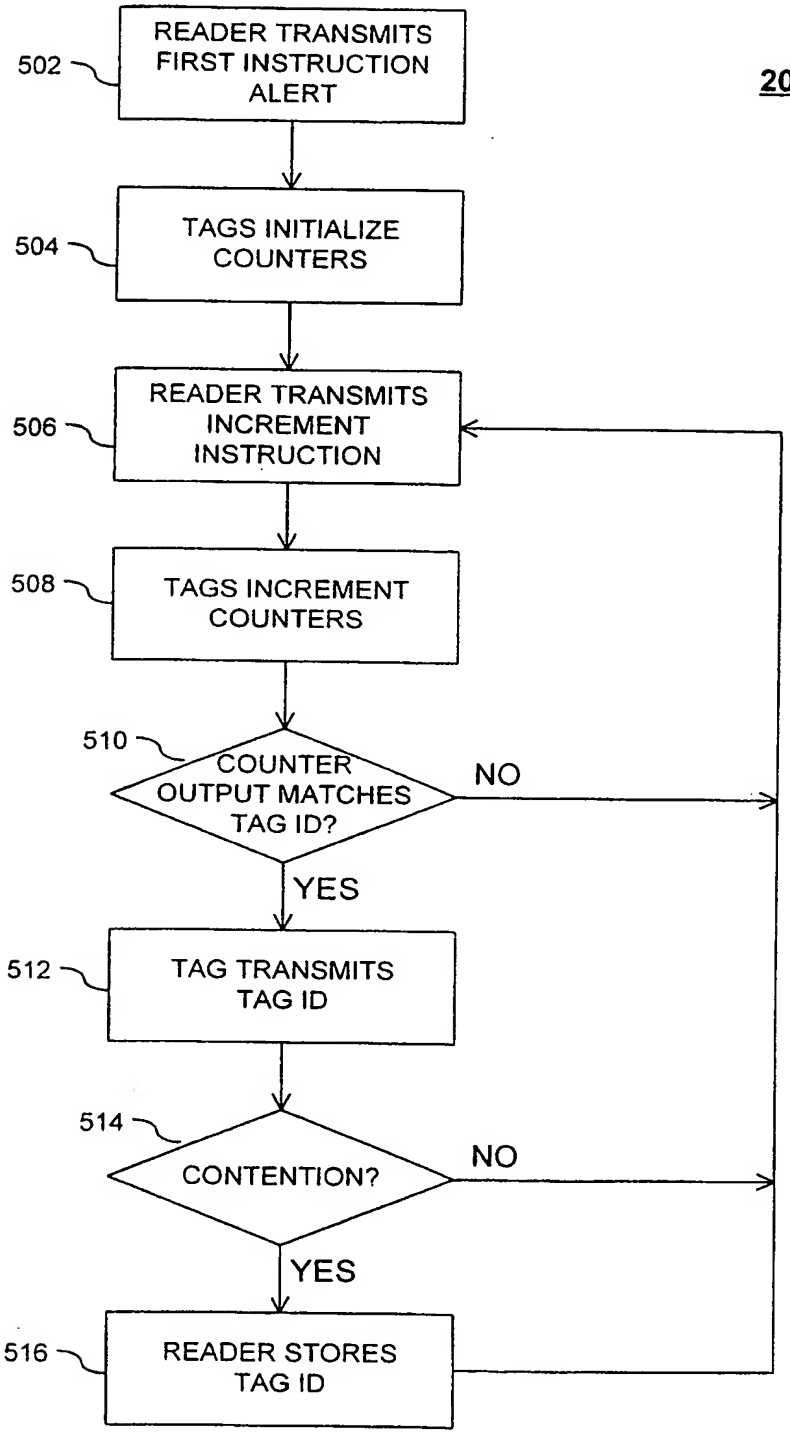
READER TRANSMITS FIRST INSTRUCTION ALERT
502
202
TAGS INITIALIZE COUNTERS
504
READER TRANSMITS INCREMENT INSTRUCTION
506
TAGS INCREMENT COUNTERS
508
510
COUNTER OUTPUT MATCHES TAG ID?
NO
YES
TAG TRANSMITS TAG ID
512
514
CONTENTION?
NO
YES
READER STORES TAG ID
516

FIG. 5

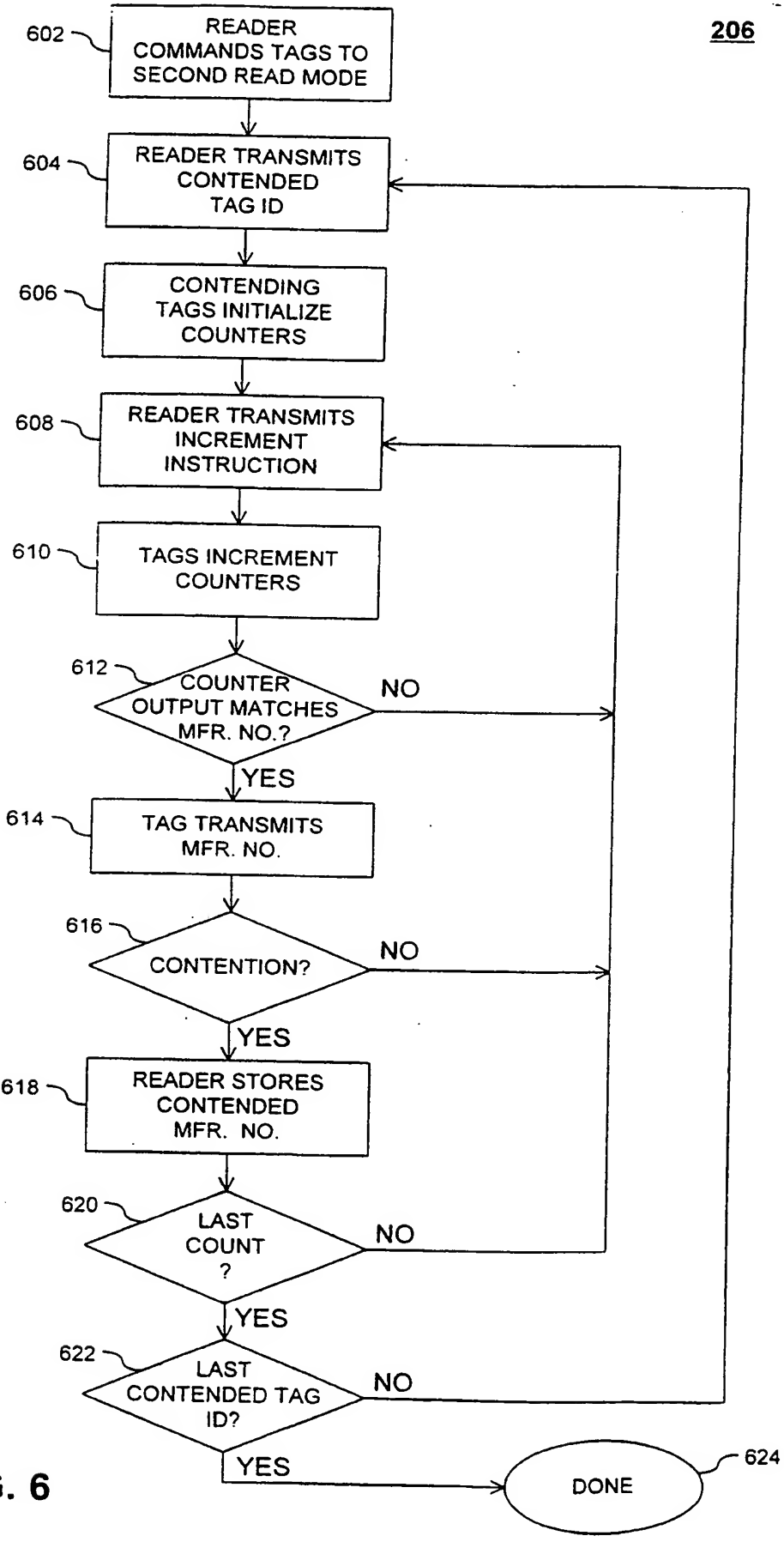
206
602
READER COMMANDS TAGS TO SECOND READ MODE
604
READER TRANSMITS CONTENDED TAG ID
606
CONTENDING TAGS INITIALIZE COUNTERS
608
READER TRANSMITS INCREMENT INSTRUCTION
610
TAGS INCREMENT COUNTERS
612
COUNTER OUTPUT MATCHES MFR. NO.?
NO
YES
614
TAG TRANSMITS MFR. NO.
616
CONTENTION?
NO
YES
618
READER STORES CONTENDED MFR. NO.
620
LAST COUNT ?
NO
YES
622
LAST CONTENDED TAG ID?
NO
YES
624
DONE

FIG. 6

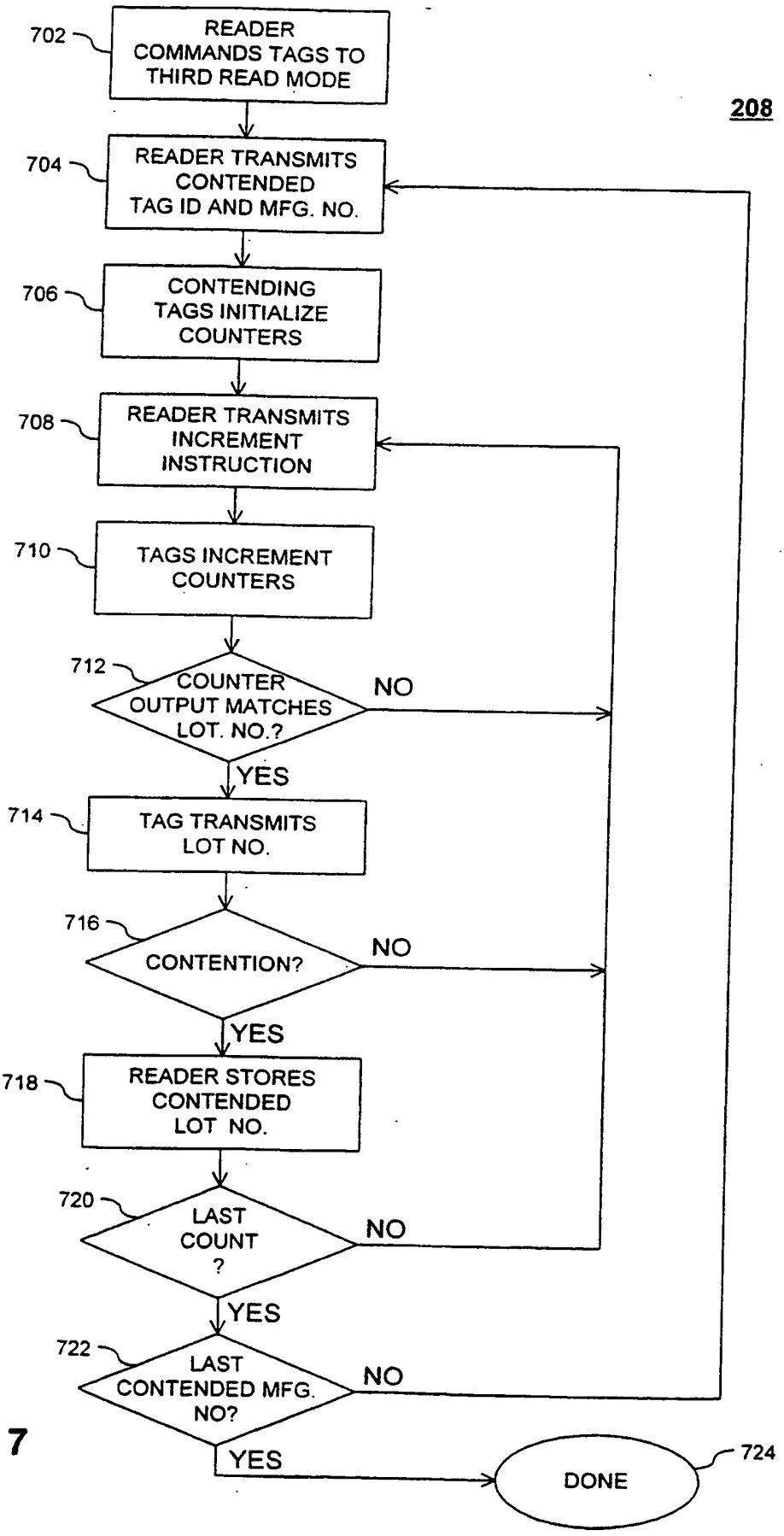
208
702
READER COMMANDS TAGS TO THIRD READ MODE
704
READER TRANSMITS CONTENDED TAG ID AND MFG. NO.
706
CONTENDING TAGS INITIALIZE COUNTERS
708
READER TRANSMITS INCREMENT INSTRUCTION
710
TAGS INCREMENT COUNTERS
712
COUNTER OUTPUT MATCHES LOT. NO.?
NO
YES
714
TAG TRANSMITS LOT NO.
716
CONTENTION?
NO
YES
718
READER STORES CONTENDED LOT NO.
720
LAST COUNT ?
NO
YES
722
LAST CONTENDED MFG. NO?
NO
YES
724
DONE

FIG. 7

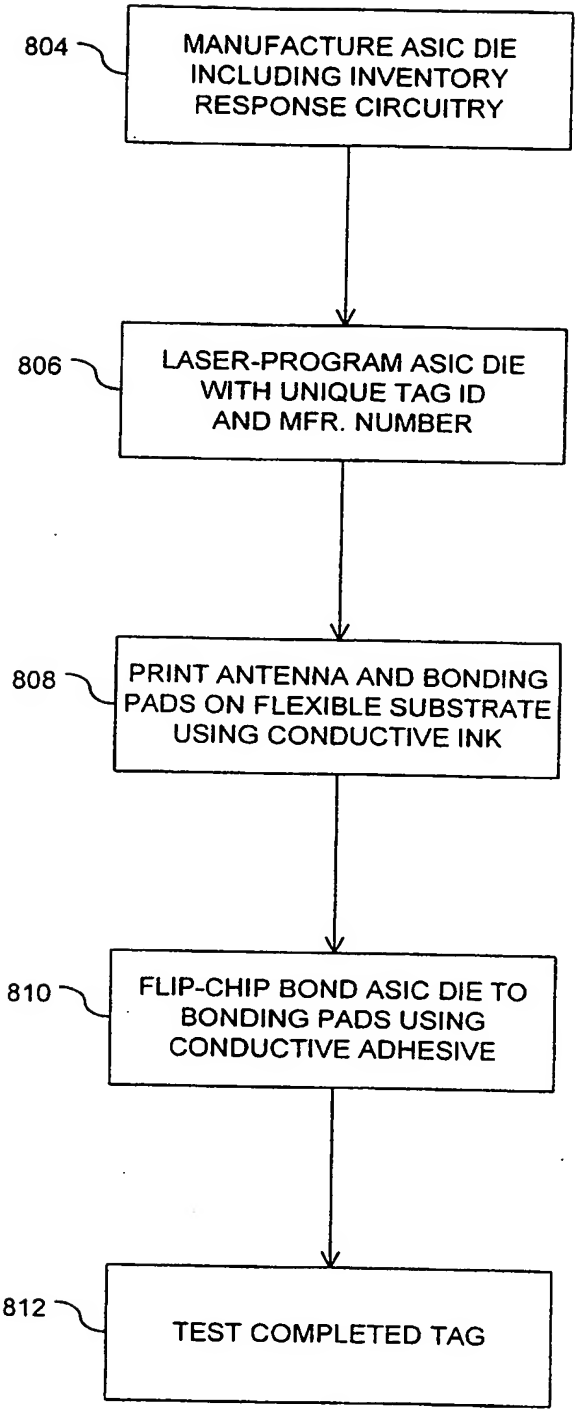
804
MANUFACTURE ASIC DIE INCLUDING INVENTORY RESPONSE CIRCUITRY
806
LASER-PROGRAM ASIC DIE WITH UNIQUE TAG ID AND MFR. NUMBER
808
PRINT ANTENNA AND BONDING PADS ON FLEXIBLE SUBSTRATE USING CONDUCTIVE INK
810
FLIP-CHIP BOND ASIC DIE TO BONDING PADS USING CONDUCTIVE ADHESIVE
812
TEST COMPLETED TAG

FIG. 8

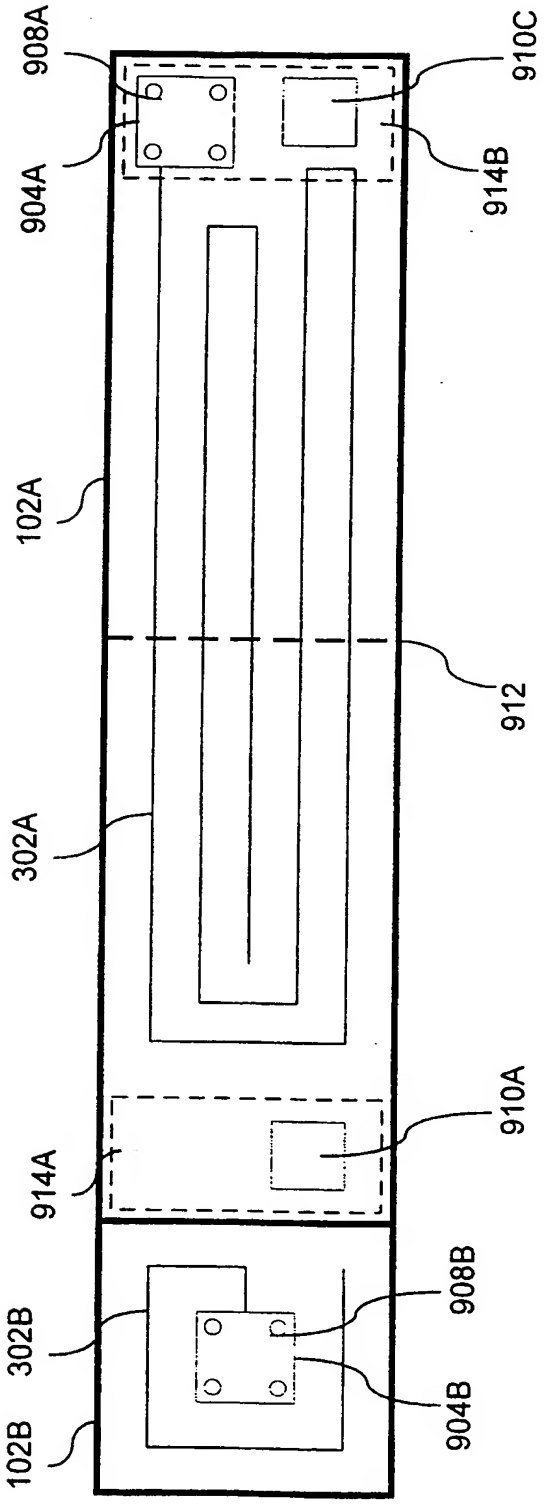
908A
910C
904A
914B
102A
912
302A
910A
914A
908B
302B
904B
102B

FIG. 9

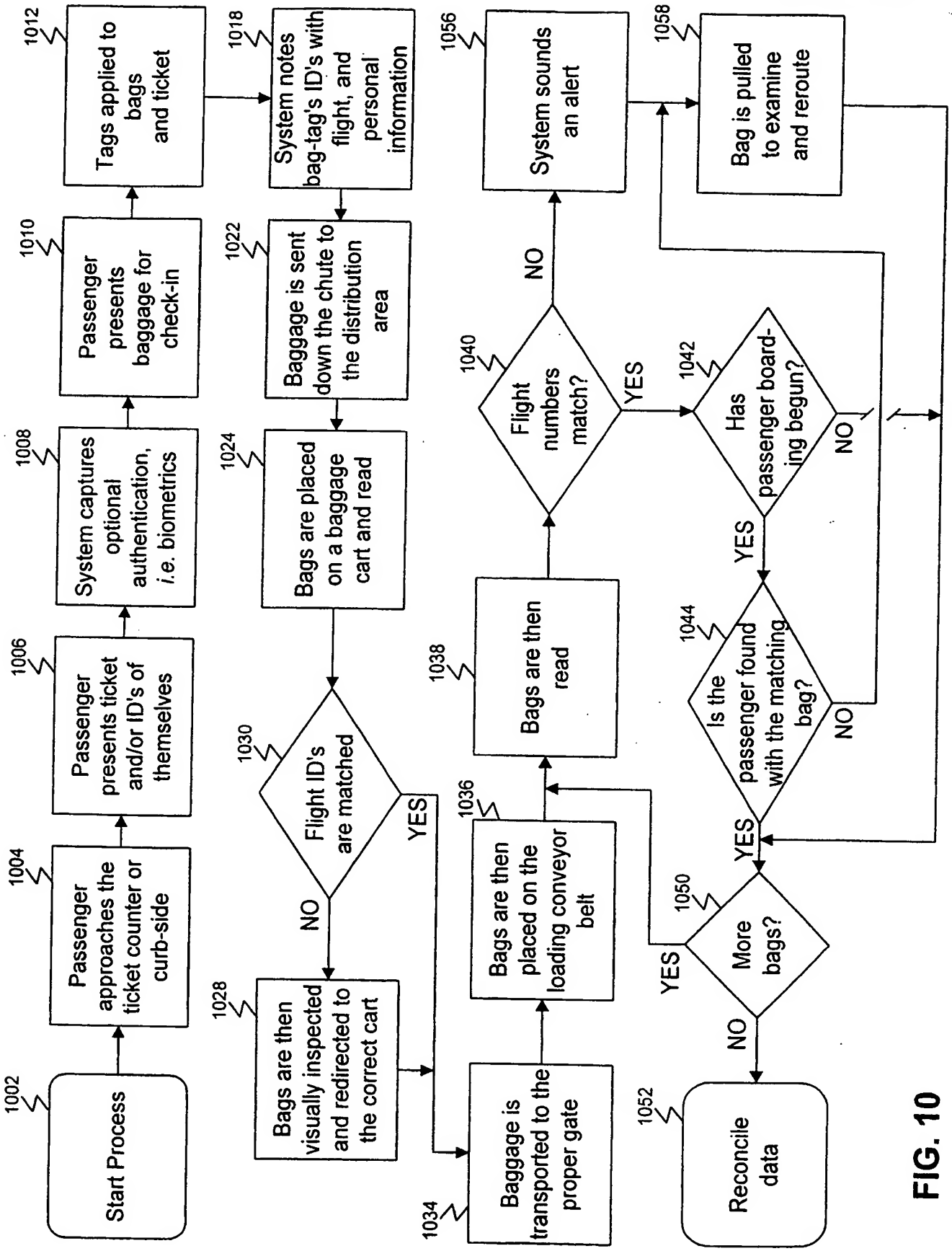
1002
Start Process
1004
Passenger approaches the ticket counter or curb-side
1006
Passenger presents ticket and/or ID's of themselves
1008
System captures optional authentication, i.e. biometrics
1010
Passenger presents baggage for check-in
1012
Tags applied to bags and ticket
1018
System notes bag-tag's ID's with flight, and personal information
1022
Baggage is sent down the chute to the distribution area
1024
Bags are placed on a baggage cart and read
1030
Flight ID's are matched
NO
YES
1028
Bags are then visually inspected and redirected to the correct cart
1034
Baggage is transported to the proper gate
1036
Bags are then placed on the loading conveyor belt
1038
Bags are then read
1040
Flight numbers match?
NO
YES
1042
Has passenger boarding begun?
NO
YES
1044
Is the passenger found with the matching bag?
NO
YES
1050
More bags?
YES
NO
1052
Reconcile data
1056
System sounds an alert
1058
Bag is pulled to examine and reroute

FIG. 10